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FUMIGATION OF SWEETPOTATOES WITH METHYL BROMIDE FOR THE DESTRUCTION OF THE SWEETPOTATO WEEVIL

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Introduction

The use of methyl bromide to free sweetpotatoes and sweetpotato draws from the various stages of the sweetpotato weevil (Cylas formicarius elegantulus (Summers)) has been the subject of investigations for several years at the Bureau of Entomology and Plant Quarantine field laboratory at Sunset, La. Easter 2/ reported in 1940 on the effectiveness of this fumigant against the weevil, and Phillips et al. 3/ reported in 1943 on the fumigation of draws and vine cuttings. In this paper are given the results of experiments in the fumigation of table stock potatoes to permit movement from infested areas to markets in noninfested areas.

Fumigation Equipment

All the fumigation tests were made in chambers equipped with fans for circulation and with thermostatically controlled heating units. These chambers are described in the reports cited above.

1/ This work was conducted in cooperation with the Division of Domestic Plant Quarantine and the Louisiana State Department of Agriculture and Immigration. The latter organization provided laboratory quarters, insect material, and labor.

2/ Easter, Stephen S. 1940. Fumigation of Sweetpotatoes with Methyl Bromide for Control of the Sweetpotato Weevil. Jour. Econ. Ent. 33 (6): 921-926.

3/ Phillips, G. L., S. S. Easter, and G. Horaist, Jr. 1943. Methyl Bromide Fumigation for Control of the Sweetpotato Weevil and its Effect on Yield. Jour. Econ. Ent. 36 (1): 98-101.

Weevil Mortality Studies

The various stages of the sweetpotato weevil when imbedded in potatoes required a much higher dosage schedule than necessary for the fumigation of draws and vine cuttings.

Easter obtained complete mortality of all stages of the weevil imbedded in sweetpotatoes with 20 ounces per 1,000 cubic feet for 10 hours at 74 - 82° F., and with 55 ounces per 1,000 cubic feet for 5 hours.

Further tests were made by using dosage schedules of 15, 20, and 25 ounces for 24 hours at 70°, and 55 ounces for 4 and 5 hours at 70°. The 15-ounce dosage permitted considerable survival, while survival was slight with the 20-ounce dosage, and mortality was complete with 25 ounces. Tests with 55 ounces for 4 and 5 hours also showed complete mortality. These tests are summarized in table 1.

The dosage rate of 55 ounces per 1,000 cubic feet for 4 hours at 70° F. was selected for further study on the basis of the above results. At this time the schedule was converted to read in pounds instead of ounces, to conform with other studies, and 3.5 pounds (56 ounces) per 1,000 cubic feet were used thereafter.

Table 1.--Summary of tests of methyl bromide fumigation at 70° F. on various stages of the sweetpotato weevil. All dosages per 1,000 cubic feet.

Dosage	Number of insects dead			Number of insects alive			Percent mortality
	Adults	Larvae	Pupae	Adults	Larvae	Pupae	
15 oz./24 hrs.	2,046	4,336	2,371	115	273	63	95.1
20 oz./24 hrs.	1,139	855	1,063	0	12	2	99.6
25 oz./24 hrs.	633	732	479	0	0	0	100
55 oz./ 4 hrs.	2,933	3,818	3,593	0	0	0	100
55 oz./ 5 hrs.	2,745	6,492	3,463	0	0	0	100

The resistance of the sweetpotato weevil to methyl bromide fumigation was found to vary slightly with the different stages. The adults, eggs, and first instars were found to be the least resistant, while the third instars and pupae were the most resistant. The weevils in lightly infested sweetpotatoes were more difficult to kill than those in heavily infested ones.

Effect upon Sweetpotatoes

Easter reported losses of sweetpotatoes due to breakdown following fumigation which were apparently associated with fumigation. This effect of fumigation upon table stocks for market was therefore the subject of extensive investigation.

The first tests of fumigation of sweetpotatoes were on seed sweetpotatoes to provide clean seed for bedding. This method of control has now been largely supplanted by fumigation of the draws and vine cuttings, but the results provide a background for the treatment of table stocks.

In 1939, 140 bushels of seed sweetpotatoes were fumigated with dosage schedules of 45 ounces for 5 hours and 55 ounces for 4 and 5 hours. The loss from breakdown was not excessive except in three lots of poor grade. Larger quantities of seed stock were fumigated in cooperation with the Louisiana State Department of Agriculture and Immigration in 1940-42. In some instances heavy breakdown occurred, which was suspected of being related to the quality of the seed stocks, and further studies were accordingly made on this point.

Five lots of sweetpotatoes ranging from 47 to 60 bushels each, and of different quality, were secured from different sources. Lot 1 sweetpotatoes were small, of poor quality, and taken directly from a bulk storage pile. Lot 2 comprised carefully selected seed sweetpotatoes of No. 2 grade. Those of lot 3 were small and of average quality. Lot 4 was of good-quality, carefully handled seed sweetpotatoes. Lot 5 was of very poor quality selected from a bulk storage pile and had been handled roughly. After storage at the laboratory for several days each lot was divided, and all were loaded into two 100-cubic-foot fumigation vaults. Those in one vault were fumigated, while those in the other were held as checks. The results showed that good-quality seed sweetpotatoes, handled carefully, showed only slight breakdown resulting from fumigation. The data are summarized in table 2.

Table 2.--Breakdown in seed sweetpotatoes of different qualities when fumigated with methyl bromide. Dosage 55 ounces per 1,000 cubic feet for 4 hrs. at 70° F.

Lot No.	Condition	Fumigated		Not fumigated	
		Number of potatoes	Percent breakdown	Number of potatoes	Percent breakdown
4	good, carefully handled	3,882	2.7	3,980	0.6
2	selected, No. 2	3,822	2.0	3,785	1.5
3	average	8,002	12.1	8,286	3.6
1	small, poor	5,858	20.6	7,036	1.4
5	very poor, roughly handled	8,084	27.8	4,620	4.5

Effect of curing or drying.—In preliminary tests on the fumigation and storage of sweetpotatoes it was observed that green or uncured sweetpotatoes were less tolerant to fumigation than those that were cured. To provide definite data on this point, a lot of freshly dug green sweetpotatoes, including 10 crates of Puerto Rico and 10 of Triumph were fumigated on September 11, 1939. An equal number of Triumph were held as checks. The breakdown was high in both varieties; 31.2 percent in Puerto Rico and 60.7 per cent in Triumph, as compared with 3.4 percent in the unfumigated Triumph. The heaviest breakdown occurred during the first week following fumigation. Rotting sweetpotatoes removed on the 5th, 7th, 9th, 11th, 14th, 16th, and 18th days amounted to 210, 174, 23, 18, 10, 6, and 3 from the original total of 1,430 Puerto Rico sweetpotatoes; and 114, 238, 115, 65, 44, 22, and 10 from the original total of 1,003 Triumphs.

Further tests were made in the fall of 1941 with Puerto Rico sweetpotatoes obtained from a common source and all harvested the same day. Thirteen lots were fumigated at weekly intervals during the curing period, starting the day following digging and continuing for 12 weeks, with a dosage schedule of 3.5 pounds for 4 hours at 70° F. Seven crates were fumigated in each lot and one was held as a check. The breakdown dropped to a low level following the eighth day. The results are given in table 3.

Table 3.—Tolerance of sweetpotatoes to methyl bromide fumigation from the day after harvesting to 12 weeks later. Dosage 3.5 pounds per 1,000 cubic feet for 4 hours at 70° F.

Postharvesting period (in days)	Fumigated		Not fumigated	
	Number of potatoes	Percent breakdown	Number of potatoes	Percent breakdown
1	616	96.6	131	0
8	819	32.7	174	0
15	840	4.5	197	0
22	853	2.1	116	1.7
29	588	8	126	4
36	653	10.6	158	0.6
43	695	6	162	0
50	844	1.4	142	0
57	714	2.2	121	0
64	788	5.6	126	0
71	639	7.8	205	0
78	608	4.3	82	0
85	415	7	99	0

Cured sweetpotatoes were fumigated at 12 weekly intervals, beginning January 29, 1942. Careful temperature records were made for each lot during fumigation and for one week following, which will be referred to later. The breakdown in these lots ranged from 0.3 to 22.7 percent. The first lot showed the least breakdown and the last lot the highest, but there was no definite trend of increase from one extreme to the other. These results are given in table 4.

Table 4.--Tolerance to methyl bromide fumigation of sweetpotatoes taken from storage at midseason. Tests made at weekly intervals between January 29 and April 22, 1942. Dosage 3.5 pounds per 1,000 cubic feet for 4 hours at 70° F.

Test No.	Fumigated		Not fumigated	
	Number of potatoes	Percent breakdown	Number of potatoes	Percent breakdown
1	736	0.3	100	0
2	827	4.6	115	2.6
3	815	7.5	110	0
4	845	7.5	110	0.9
5	1,025	2	130	0
6	825	1.6	125	0
7	1,015	0.9	165	0.6
8	835	8.7	100	1
9	885	7.8	100	0
10	1,030	2	125	0
11	955	13.9	140	0
12	1,035	8.3	150	0
13	930	22.7	130	0.8

The breakdown resulting from a dosage of 55 ounces for 4 hours at 70°, and 20 ounces for 24 hours at 70°, was compared in another series of tests. Little difference was evident, as shown below.

	Number of sweetpotatoes	Percent breakdown
20-ounce dosage	2,755	1.74
55-ounce dosage	2,552	2.03
Check	2,501	0.43

The breakdown of sweetpotatoes that had been kiln-dried with artificial heat, 4/ as compared with green potatoes, was determined in another series of tests. The kiln-dried lots were kept at 80° to 85° for 10 days before fumigation. The results showed a very definite advantage from kiln drying, with only 2.9 percent breakdown in 6,445 sweetpotatoes as compared with 56.4 percent breakdown in 2,508 green sweetpotatoes.

These tests were repeated, but with the sweetpotatoes stored at natural temperatures for 2 weeks before kiln drying with artificial heat at 80° to 85° for 10 days. There was practically no difference between the rates of breakdown in naturally cured and kiln-dried sweetpotatoes, indicating that curing at normal temperatures existing at Sunset was as advantageous as kiln drying for the 24-day period. This is in agreement with the results given in table 3, where breakdown dropped to a low level after the eighth day of curing. The breakdown averaged 3 percent for 3,351 normally cured sweetpotatoes and 3.8 percent for 12,019 kiln-dried sweetpotatoes.

Effect of ventilation.--When the cured sweetpotatoes used in the tests of 1940 were removed from the fumigation chamber and placed in postfumigation storage they were stacked in 4 stacks of 5 crates each. Examinations at the end of a 10-day period to determine the amount of breakdown revealed that the breakdown in the crate at the bottom of each stack was more than in the other crates. This breakdown averaged 5.74 percent in 1,427 sweetpotatoes in the bottom crates as compared with 2.1 percent in 4,930 in the other crates. This difference is attributed to lack of ventilation of the bottom crates. Subsequent lots of sweetpotatoes were placed on a floor rack so constructed that the bottom crates were 8 inches from the floor, and under these conditions the bottom crates showed no greater breakdown than those in other parts of the storage room.

Effect of postfumigation temperature.--The observations on breakdown in green and cured sweetpotatoes showed a great reduction in loss following proper curing or drying. However, there were still instances of breakdown, totaling 5 to 10 percent or more, in fumigated sweetpotatoes which were supposedly well cured. In attempts to determine the causes of such losses, attention was focused on the effect of postfumigation temperatures. In his earlier studies Easter had noted increased breakdown when postfumigation temperatures were below 70°

4/ In the Sunset area curing is done by utilizing natural heat, which usually ranges up to 85° F. In other sweetpotato areas the application of artificial heat is often necessary.

In the tests recorded in table 4, records of the temperature of the storage room and of the sweetpotatoes were kept for 7 days following fumigation. A study of these records shows that where the temperature of the sweetpotatoes dropped below 70° during the first or second night following fumigation, the resulting breakdown was greater. In this series, lots 1, 2, 6, and 7 remained at 70° for the first two nights after fumigation and breakdown averaged 1.02 percent. In lots 5 and 10 the temperature fell below 70° either the first or second night and breakdown averaged 2.03 percent. In lots 3 and 4 the temperature dropped below 70° both nights and breakdown averaged 7.01 percent. Lots 8, 9, 11, 12, and 13 are not considered in this connection in these instances, as ventilation was a complicating factor.

A large-scale test was made to determine if a postfumigation temperature at 70° or above would prevent breakdown, and the length of postfumigation period that would be necessary for best results. Sweetpotatoes were stored for 2 weeks at 70° and then fumigated, after which one lot was immediately removed to ordinary storage (below 70°) and others were kept at 70° for 1, 2, 3, 4, and 5 days, respectively, before being removed to the same ordinary storage. This test was replicated four times. The greatest breakdown occurred in the lots not receiving any postfumigation storage at 70° The other lots all had relatively little breakdown in excess of their respective checks (see table 5).

Table 5.--The influence of different periods of postfumigation storage at 70° on breakdown in fumigated sweetpotatoes. Dosage 3.5 pounds per 1,000 cubic feet for 4 hours at 70° F.

Postfumigation storage at 70° (in days)	Fumigated		Not fumigated	
	Number of potatoes	Percent breakdown	Number of potatoes	Percent breakdown
0	984	9.4	434	1.2
1	1,068	2.2	402	1.9
2	995	1.1	425	0.5
3	1,000	0.4	437	0.5
4	971	1.9	431	1.4
5	918	2.6	413	1.5

A postfumigation storage temperature of 80° was compared with one of 70° in another series and was replicated 8 times. In these tests all lots were divided immediately following fumigation at 70°, one-half going into 70° storage and the other half into 80° storage for 3 days, after which they were all removed to ordinary storage.

The breakdown was exceptionally low in both groups, averaging 0.52 percent for 8,537 sweetpotatoes at 70° and 0.36 percent for 8,738 at 80° The checks averaged 0.16 and 0.32 percent respectively. It was concluded that there was no difference in results from post-fumigation temperatures of 70° and 80°

Commercial application.--Seventy-two carloads of sweetpotatoes were fumigated and shipped under the supervision of the Louisiana State Department of Agriculture and Immigration during April and May, 1942. In all instances they were fumigated in cars with a dosage schedule of 3.5 pounds per 1,000 cubic feet for 4 hours at 70° or above. At that season the prevailing temperatures were above 70°

The condition of the sweetpotatoes upon arrival at their destinations was checked in 16 of the 72 cars. Those in 10 of the 16 cars were in good condition with less than 2 percent breakdown showing in test samples. Two of the remaining cars revealed very high breakdown, in one instance apparently associated with poor quality, in the other with overloading and high temperatures. The remaining four had breakdowns of 7.8, 8.1, 14, and 5 percent. In the first three of these the loads were 871 to 1,006 crates, as compared with a normal carload of 504 crates, which undoubtedly interfered with ventilation following fumigation.

The results of these treatments were interpreted to mean that under proper conditions the fumigation of carload lots of sweetpotatoes is commercially practicable.

The prevailing temperatures were sufficiently high so that a drop in postfumigation temperature, as discussed elsewhere in this paper, was not a factor.

Varietal tolerance.--At various times the tolerance of new varieties to methyl bromide fumigation was tested. The sweetpotatoes were all furnished by the Bureau of Plant Industry field station at Baton Rouge, La., and in every instance were well cured. A dosage of 3.5 pounds per 1,000 cubic feet for 4 hours at 70° was used.

On March 3, 1941, small lots of 41 varieties and strains were fumigated without any resulting injury. On May 1, 1941, 51 additional varieties, in addition to 9 included in the March tests, were fumigated, also without any resulting injury. On January 22, 1942, one-bushel lots of 48 varieties were treated, with only neglible losses from breakdown.

Summary

The results of recent experiments at Sunset, La., to free sweetpotato table stock from the sweetpotato weevil by methyl bromide fumigation are given.

A higher dosage schedule than that determined necessary for draw or vine-cutting fumigation was found to be required. All stages of the weevil imbedded in potatoes were killed by exposure to a dosage of 3.5 pounds of methyl bromide per 1,000 cubic feet of vault space for 4 hours at 70° F. or above.

Newly harvested "green" sweetpotatoes were found to be severely injured by fumigation, whereas those cured 15 days or more or kiln dried for 10 days at 80° to 85° were not seriously injured.

Proper ventilation following fumigation was found to decrease the amount of breakdown attributable to fumigation.

Breakdown in cured sweetpotatoes following fumigation was found to be associated with postfumigation storage temperatures. Extensive tests showed that sweetpotatoes held at 70° for 24 hours had much less breakdown than those removed immediately to ordinary storage at less than 70°. There was no apparent difference in results with postfumigation storage temperatures of 70° and 80°

Sweetpotatoes fumigated in refrigerator freight cars in April and May arrived at their destination in sound and marketable condition when they were properly handled. Breakdown followed in cars that were overloaded or overheated, or that contained poor quality sweetpotatoes.

There appeared to be no appreciable differences in breakdown between varieties following fumigation.